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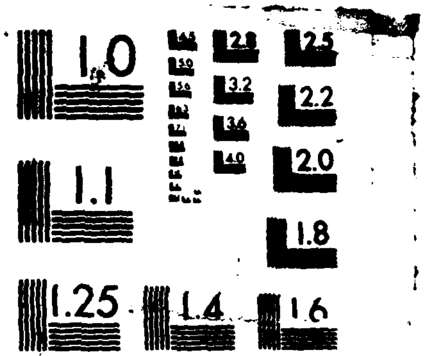

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Conductivity fluctuations ascribed to diffusion noise of the mobile ions have been observed in single crystal and polycrystalline ceramic Pb Beta"alumina. The observed noise levels are much greater and the temperature dependence stronger than predicted by the standard expression for diffusion noise. The calculated effective ion density, 10^{10} ions/cm^3, is two orders of magnitude larger than that of Na Beta"alumina and Ag Beta"alumina. This can be attributed to smaller correlation effects between the mobile ions because of the lesser actual mobile ion density in Pb Beta"alumina.

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NOISE IN LEAD β" ALUMINA

by

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I. INTRODUCTION

Conductivity fluctuations ascribed to diffusion noise of the mobile ions have been reported in both sodium[1] and silver[2] β"alumina. The observed noise levels are much greater and the temperature dependence stronger than predicted by the standard expression for diffusion noise.[3] It is supposed that the discrepancies arise from correlation effects between the mobile ions. This work reports on experimental measurements of conductivity fluctuations in single crystal and ceramic Pb β"alumina in which the mobile ion density is one-half of that in sodium and silver conductors because the mobile ions are doubly charged. Correlation effects might be expected to be different in this case because of the smaller ion density.

II. EXPERIMENTAL TECHNIQUE

Single crystals[4] and ceramic samples[5] of Na β"alumina[5], 5x5x0.5 mm^3, are converted[6] to Pb β"alumina by immersion in molten $PbCl_2$ at 550°C for 24 hours under a partial pressure of oxygen. The converted crystals are clear and the measured weight change indicates essentially complete exchange of one lead ion for two sodium ions. As in previous studies,[1,2] the corners of the square samples are sealed into plastic test tubes containing saturated aqueous $Pb(NO_3)_2$ to provide longitudinal current contacts and transverse noise contacts. Noise levels at the transverse contacts are measured with a PAR 113 preamplifier and a digital FFT analyzer.

III. EXPERIMENTAL RESULTS

Aqueous lead nitrate yields very low noise contacts after aging for several hours. Typical noise spectra are shown in Figure 1. At zero current, Nyquist noise is observed above amplifier noise for frequencies greater than about 30 Hz. Room temperature conductivity determined from the sample resistance calculated using the observed Nyquist noise level is 8.3×10^{-3} $(\text{ohm-cm})^{-1}$, in good agreement with literature values.[6] Current noise spectra vary as $f^{-3/2}$, characteristic of diffusion noise,[3] and increase with the square of the current. As shown in Figure 1, both transverse and longitudinal noise levels are

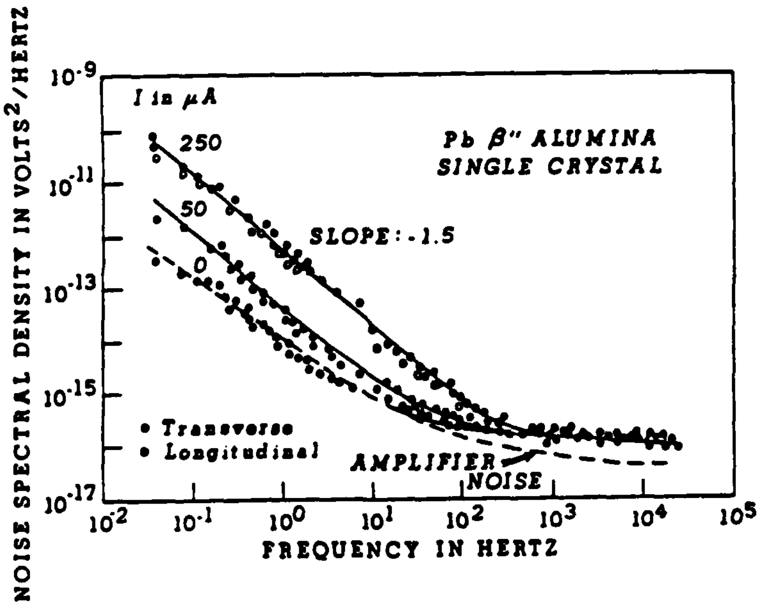

Figure 1. Transverse and Longitudinal Noise Spectra of a Pb β" Alumina Single Crystal at Room Temperature

the same, indicating the absence of contact current noise and confirming that the observed noise is due to bulk conductivity fluctuations. This has previously been observed in the case of Ag β"alumina but not for Na β"alumina.

Essentially identical results are seen for polycrystalline ceramic specimens. The noise levels are similar, indicating that the polycrystalline grain structure does not markedly influence the observed noise. This agrees with results previously reported for both sodium[1] and silver[2] β"alumina. All current noise spectra vary as $f^{-3/2}$, characteristic of diffusion noise.

IV. DIFFUSION NOISE

The voltage noise spectral density, S(V,f,T), arising from diffusion can be written[3]

$$\frac{S(V,f,T)}{V^2} = \frac{4}{N}\left(\frac{D}{2L^2}\right)^{1/2} \omega^{-3/2} \qquad (1)$$

where N is the number of diffusing entities, D is the diffusion constant, L is the sample length, and V is the average voltage across the sample. This expression is valid above a characteristic frequency given by $\omega_0 = 2D/L^2$. Below ω_0 the spectrum flattens, becoming a constant in the case of three-dimensional diffusion.

The observed noise signals are thermally activated, Figure 2. The activation energy in the case of Nyquist noise (0μA,5kHz) agrees with conductivity values[6] for both single crystal and ceramic samples. The temperature dependance for diffusion noise (I>0,10Hz) is greater than can be accounted for by Equation (1). This is consistent with previous results for sodium and silver β"alumina.

As in the case of sodium and silver β"alumina, the noise level predicted by Equation (1) is many orders of magnitude less than that observed in the Pb β"alumina samples. This is attributed to correlation effects between the diffusing ions which may lead to an effectively smaller ion concentration for diffusion noise. Equation (1) can be used to calculate an effective ion density as a means of comparing experimental results between the different ion species.

The calculated effective ion density for the lead conductors is 10^{10} ions/cm^3, larger than that of the other two, which may result from the smaller actual ion density in these specimens because the lead ions are doubly charged. The known mobile ion density in

β"alumina is approximately 10^{21} ions/cm^3, so that the larger value in the case of lead may suggest smaller correlation effects.

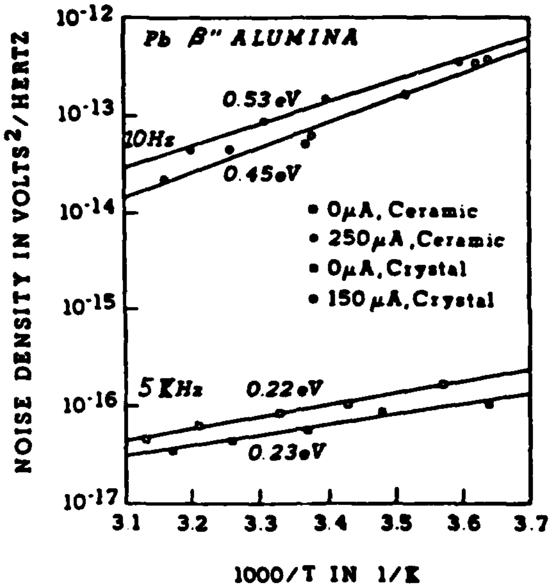

Figure 2. Temperature Dependance of Nyquist Noise (5kHz) and Diffusion Noise (10Hz) of Single Crystal and Ceramic Pb β"Alumina.

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